

THE CHRONOLOGY OF LATE QUATERNARY FLUVIAL ACTIVITY IN PART OF THE MILFELD BASIN, NORTHEAST ENGLAND

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ABSTRACT

The sediment stratigraphy of a 4 m thick intercalated Holocene alluvial fill and valley floor peat at a site in the Milfield Basin, Northumberland, has been dated by a series of eight ^{14}C assays, and related to a previously analysed pollen record. The sequence extends from the earliest Holocene until c. 2800 cal. BP. Prior to the onset of peat inception, substantial amounts of channel-trenching can be demonstrated to have occurred in the Milfield Basin during the Loch Lomond Stadial. There is no measurable early Holocene accelerated fluvial activity, but a major flooding event occurred at c. 7500 cal. BP, much earlier than recorded elsewhere in the region. The explanation for this is not clear. However, the cessation of mid-Holocene overbank sedimentation at c. 4000–3500 cal. BP is tentatively correlated with slope stability associated with woodland regeneration. © 1998 John Wiley & Sons, Ltd.

KEY WORDS: fluvial stratigraphy; Late Devensian; Holocene; northern England; radiocarbon dating

INTRODUCTION

The Milfield Basin in northernmost Northumberland (Figures 1 and 2) is the largest alluvial basin in northeast England (c. 3000 ha), and receives drainage from many rivers, draining both the andesitic lavas of the Cheviot Hills to the west and southwest and the more subdued ridges of the Carboniferous Fell Sandstone to the east. The basin itself is underlain at depths of several metres by mudstones and shales of the Carboniferous Cementstone Group, but this is rarely exposed (Figure 2; Payton, 1980), being concealed by considerable thicknesses, up to 60 m, of late Quaternary sediments.

Many aspects of Late Devensian deglaciation in and around the basin (e.g. Clapperton, 1970, 1971), and periglaciation (Douglas, 1991; Douglas and Harrison, 1985, 1987), and Late Devensian and Holocene soil development (Payton, 1980, 1992) have been examined. The archaeological record is particularly rich, and has been analysed by excavation and field survey (Burgess, 1984; Gates and O'Brien, 1988; Harding, 1981; Hope-Taylor, 1977; Miket, 1976, 1981). The vegetation history of the basin and the surrounding hills has been reconstructed in varying detail (Borek, 1975; Clapperton *et al.*, 1971; Davies and Turner, 1979; Turner, 1968; Tipping, 1992). However, despite the basin having substantial accumulations of fluvial sediments (Payton, 1980) there has been no published attempt to analyse the chronology of alluviation in the Late Quaternary.

Clapperton *et al.* (1971) demonstrated that mid-late Holocene fluvial aggradation near the basin could be highly significant, and this was confirmed for the Cheviots by Tipping (1992, 1994a,b) and for the Fell Sandstones near Rothbury by Macklin *et al.* (1991). Tipping's work in the Cheviots concentrated on high-gradient, gravel-rich mountain streams exhibiting high levels of channel migration and avulsion (cf. Newson, 1981). Three broadly synchronous phases of mid-late Holocene accelerated fluvial activity were proposed, using ^{14}C dates, for four of the major northerly and easterly draining valleys (Bowmont Water, Halter Burn, Wooler Water and River Breamish; Figure 1); these were 4500–4000 cal. BP, 2500–1900 cal. BP and post-300 cal. BP (Tipping, 1992, 1994a,b). However, there are uncertainties as to the completeness of these

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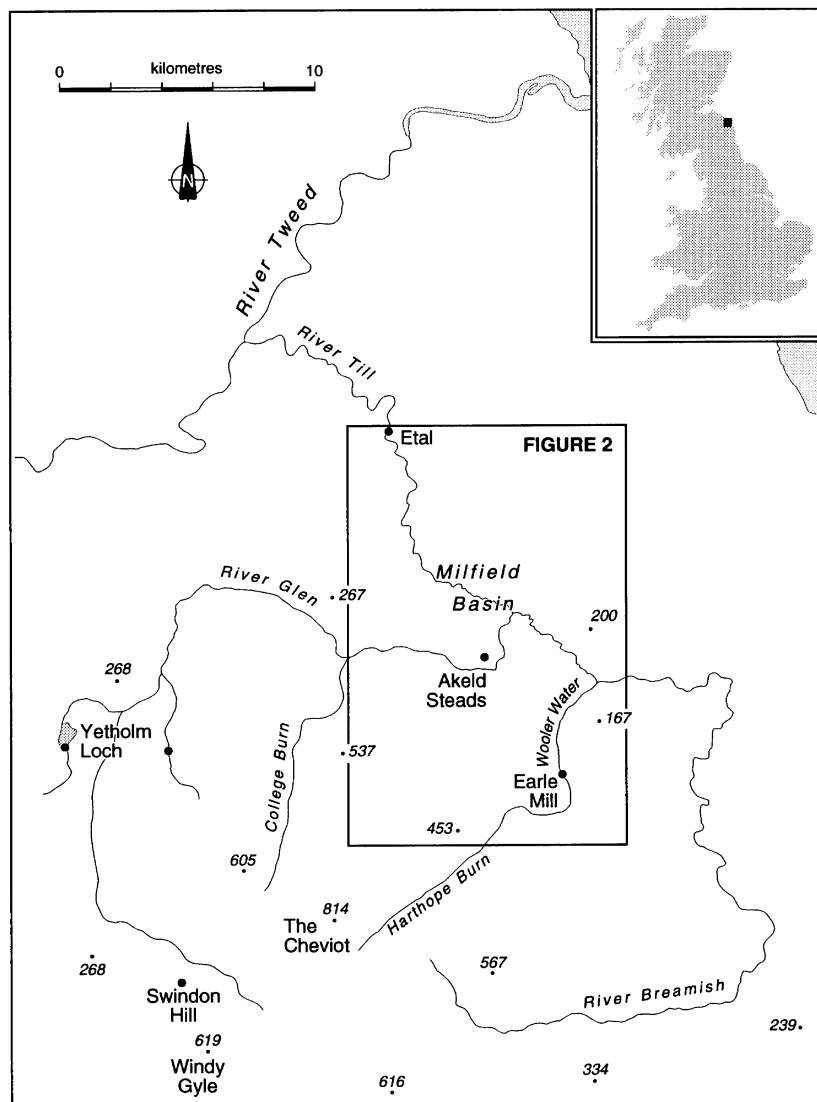


Figure 1. The location of the Milfield Basin in northern England, the drainage pattern and main summits (metres OD) of the northern and eastern Cheviot Hills, and the localities in and around the Basin discussed in the text. The location of Figure 2 is indicated

palaeofluvial records because the overall lack of dateable deposits severely limits the establishment of a chronology. Not all terrace fills have been dated; indeed, no catchment has more than one terrace fill dated, and these high-energy systems may also have eroded or buried entire fluvial aggradations. These weaknesses are clearly critical if the periodicity and associated causal factors are to be reliably assessed (Macklin and Lewin, 1994; Tipping, in press).

These problems are probably applicable to all upland streams typified by 'cut-and-fill' terrace sequences, where vertical incision, avulsion and valley widening are common. Stacked sediment fills, in which discrete sediment bodies accumulate in a layered stratigraphy through the absence of channel trenching (Macklin *et al.*, 1992), probably offer inherently more secure contexts from which to establish chronologies of fluvial behaviour. Within inland catchments these fills are characteristic of low-energy, low-gradient and stable channel river systems such as those in southern England (Burrin and Scaife, 1984; Burrin and Jones, 1994), dominated by fine-grained floodplain/overbank sediments. Peri-marine accumulations show similar stacked fills (Passmore *et al.*, 1992) though here sea-level movements rather than stream energy are influential in

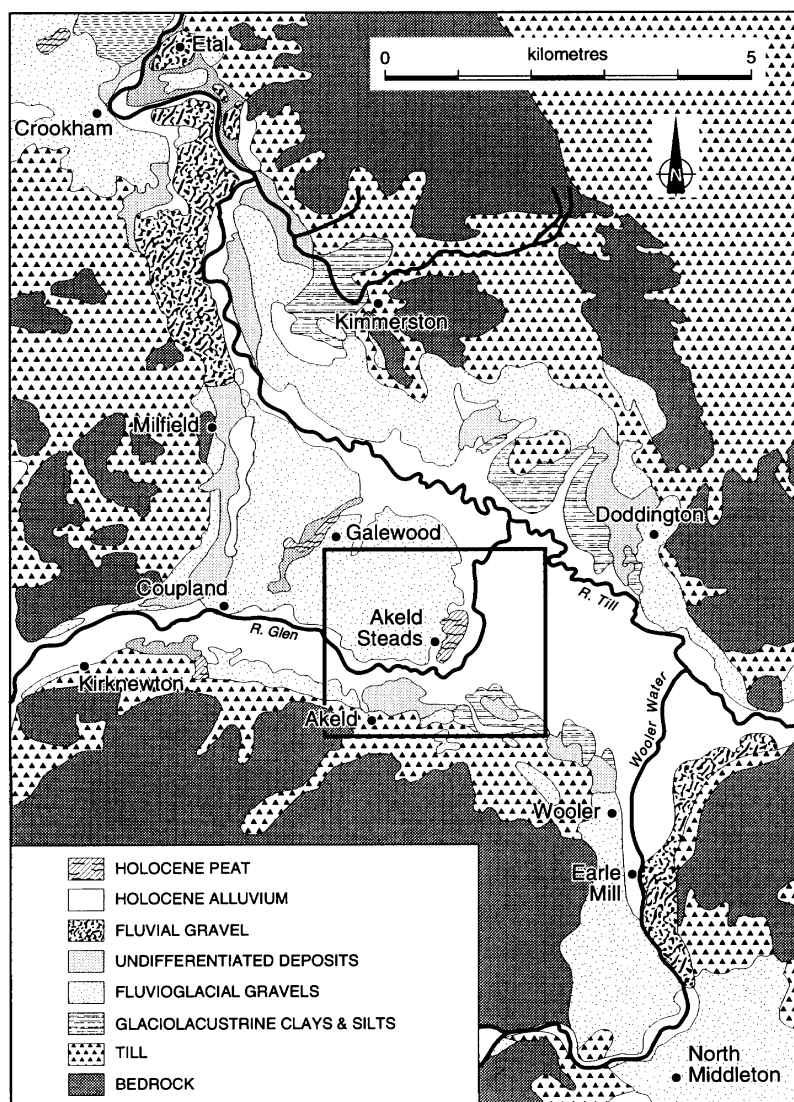


Figure 2. Distribution of superficial deposits and 'solid' geology within the Milfield Basin (after Payton, 1980). The location of Akeld Steads (Figure 3) is indicated

determining sedimentary style. Stacked fills are also present at several localities in areas with much greater relative relief, though are rarer and probably more discrete sediment bodies. They occur, for instance, where mountain streams descend with an abrupt break-of-slope to low-lying basins. Stream energies are rapidly dissipated, and the coarse gravel sediment load is dumped, so that basins are again typified by fine-grained deposits.

The Milfield Basin is one basin in which stacked fills appear to be typical. Here the sharp change in fluvial depositional style between cut-and-fill terracing to stacked aggradation is promoted by abrupt topographical changes induced by fault-controlled geological boundaries between the Cheviots and the basin floor, but sediments laid down during late Devensian deglaciation are also significant controls (below). Payton (1980, 1988) described in excess of 4 m of fine-coarse textured alluvium in broad areas roughly parallel to the present river courses. Alluvial spreads from individual catchments can in some instances be separated on colour and texture (Weatherston and Innes, unpublished data).

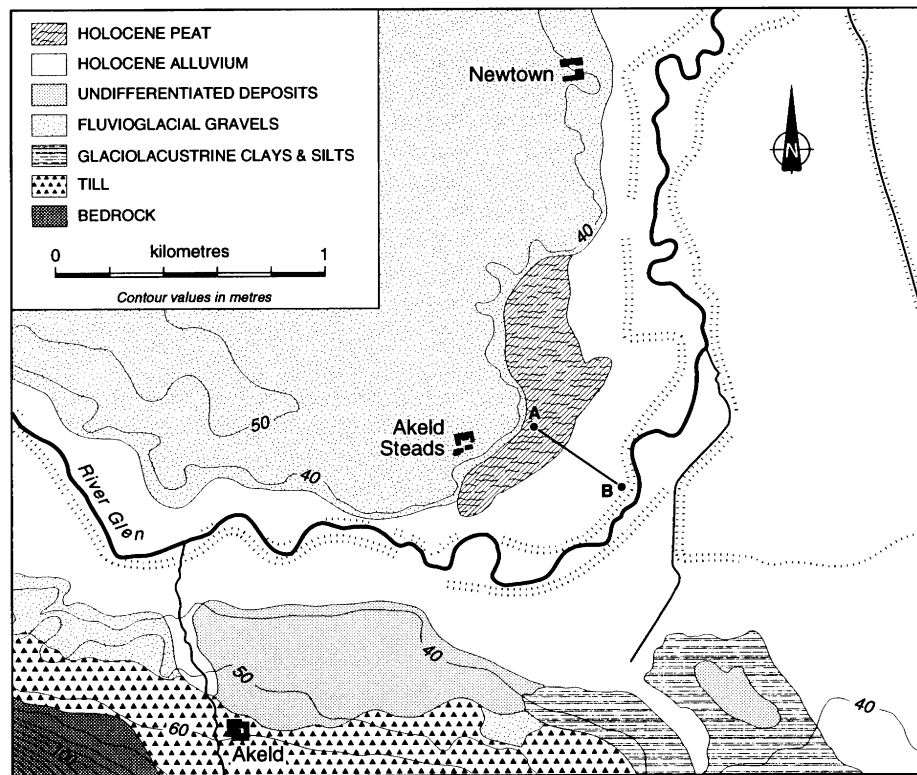


Figure 3. The area of the Milfield Basin in the vicinity of Akeld Steads, showing contours at 10.0 m intervals, surficial sediments, the position of the valley peat on the edge of the Holocene alluvium, and the line of transect A–B in Figure 4 (after Tipping, 1994c)

Stacked fills can prove difficult to date (Burrin and Scaife, 1984) through the absence of *in situ* organic matter, and chronologies have been constructed from palynology of inorganic fills (Scaife and Burrin, 1992). This may be a function of the dry climate of southern England. In northern England the increased precipitation encourages peat development whenever floodplain conditions allow. These conditions are probably those of reduced overbank sedimentation. Small patches of peat and organic-rich soils can be found as laterally continuous horizons within alluvial fills in the Milfield Basin (Weatherston and Innes, unpublished data), suggesting that alluviation was episodic. More continuous peat accumulations occur at a few localities towards the edges of the basin.

One of these basin-edge peats is at Akeld Steads, within the zone of sedimentation of the River Glen (Figures 1, 2 and 3), receiving drainage from the northern Cheviots. Here Borek (1975) produced a low-resolution 'skeletal' Holocene pollen diagram. The sediment stratigraphy at Borek's site, exhibiting periodic incursions of minerogenic sediments into the peats, suggested to Payton (1980) that here might be a suitable locality to investigate the timing of Holocene fluvial sedimentation in this part of the Milfield Basin.

In 1992 and 1993 the peats at Akeld Steads were reinvestigated by this author, with the intention of relating the Holocene alluvial chronology of this stacked fill with chronologies from the Cheviots themselves (Tipping, 1992). Borek's sediment stratigraphy was not ^{14}C dated at the time, but palynological data were used by Tipping (1994c) to estimate the principal phases of fluvial activity. That chronology has now to be rejected, because this paper provides recently obtained ^{14}C dates on the peat sequence. At a larger scale, the new work at Akeld Steads yields a contribution to the understanding of the Late Quaternary development of river systems in upland Britain.

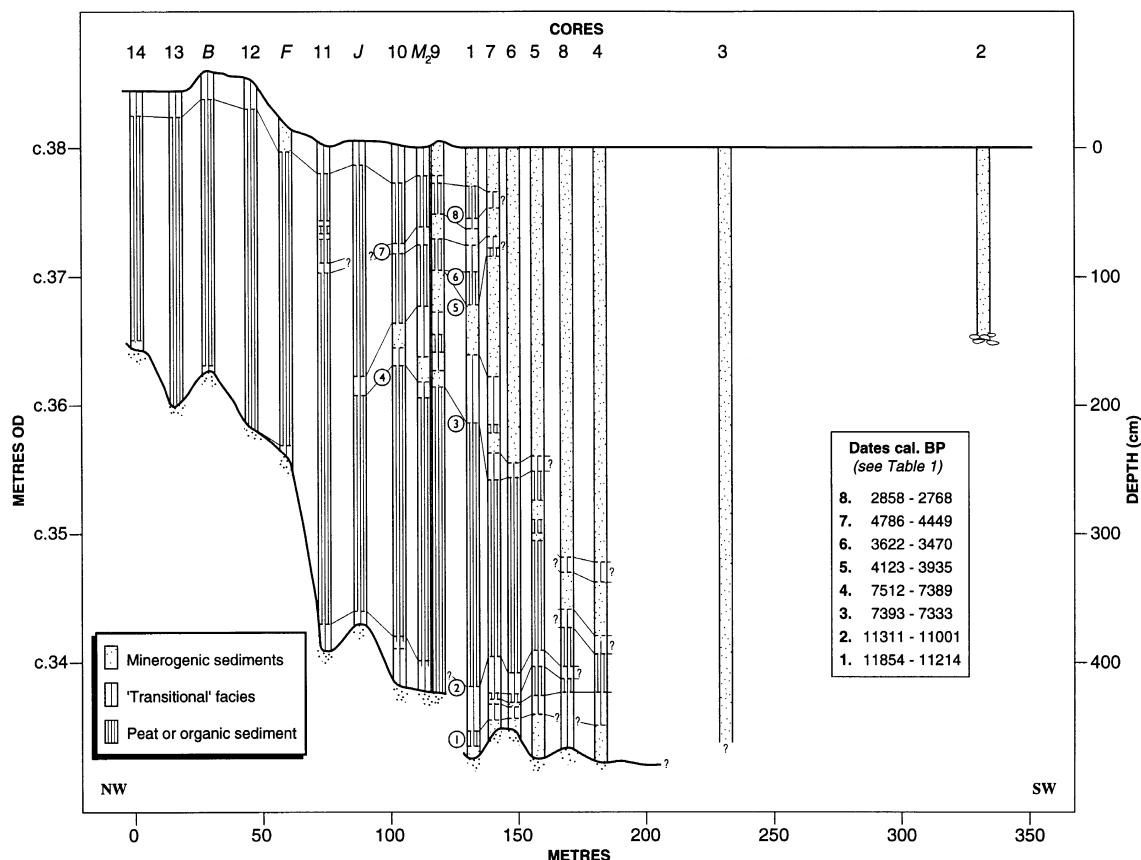


Figure 4. Simplified sediment stratigraphy of the boreholes 14 – 2 of Transect A–B at Akeld Steads. Numbered points are those of this worker; lettered points are those of Borek (1975). Borehole surfaces are surveyed to OD. Numbered circles refer to the positions of radiocarbon assays in Table 1.

THE AKELD STEADS SEDIMENT STRATIGRAPHY

Methods

The distribution of sediment types in the Milfield Basin is shown in Figure 2, and that close to Akeld Steads is depicted in Figure 3. The stratigraphy at the site was investigated by Borek (1975) on several transects, and the critical transect at right-angles to the river was extended by this worker out onto the floodplain of the River Glen (transect A–B, Figure 3) using a hand-operated Eijelkamp gouge-sampler (diameter 3.0 cm). Sediments were described in the field. The resultant stratigraphy is shown in simplified form in Figure 4, which emphasizes the representation of true peat, transitional organic-rich minerogenic facies and purely minerogenic units. This transect incorporates Borek's data (lettered boreholes), including that sequence sampled by Borek for palynology (borehole M_2).

Borek's pollen data are recalculated from the original percentage arboreal pollen (ap) sum (Borek, 1975) to a more conventional percentage total land pollen (tip) sum in Figure 5. The diagram lacks the detail to allow palaeoecological interpretation but can provide tests of the radiocarbon chronology. From critical sediment boundaries in several boreholes (Figure 4) ^{14}C samples from laterally continuous, demonstrably *in situ* peats were taken either from a 50.0 cm deep monolith tin, a wide-diameter (10.0 cm) Russian corer or a Stitz vibro-corer with 5.0 cm diameter piston chamber. Eight samples were assayed at the NERC ^{14}C facility at East Kilbride (Table I). The temporal resolution of some of these samples is less than satisfactory, with 10.0 cm thick slices, but broad conclusions can be drawn. Assays have been calibrated (Table I) by CALIB 3.0 (Stuiver and Reimer, 1993).

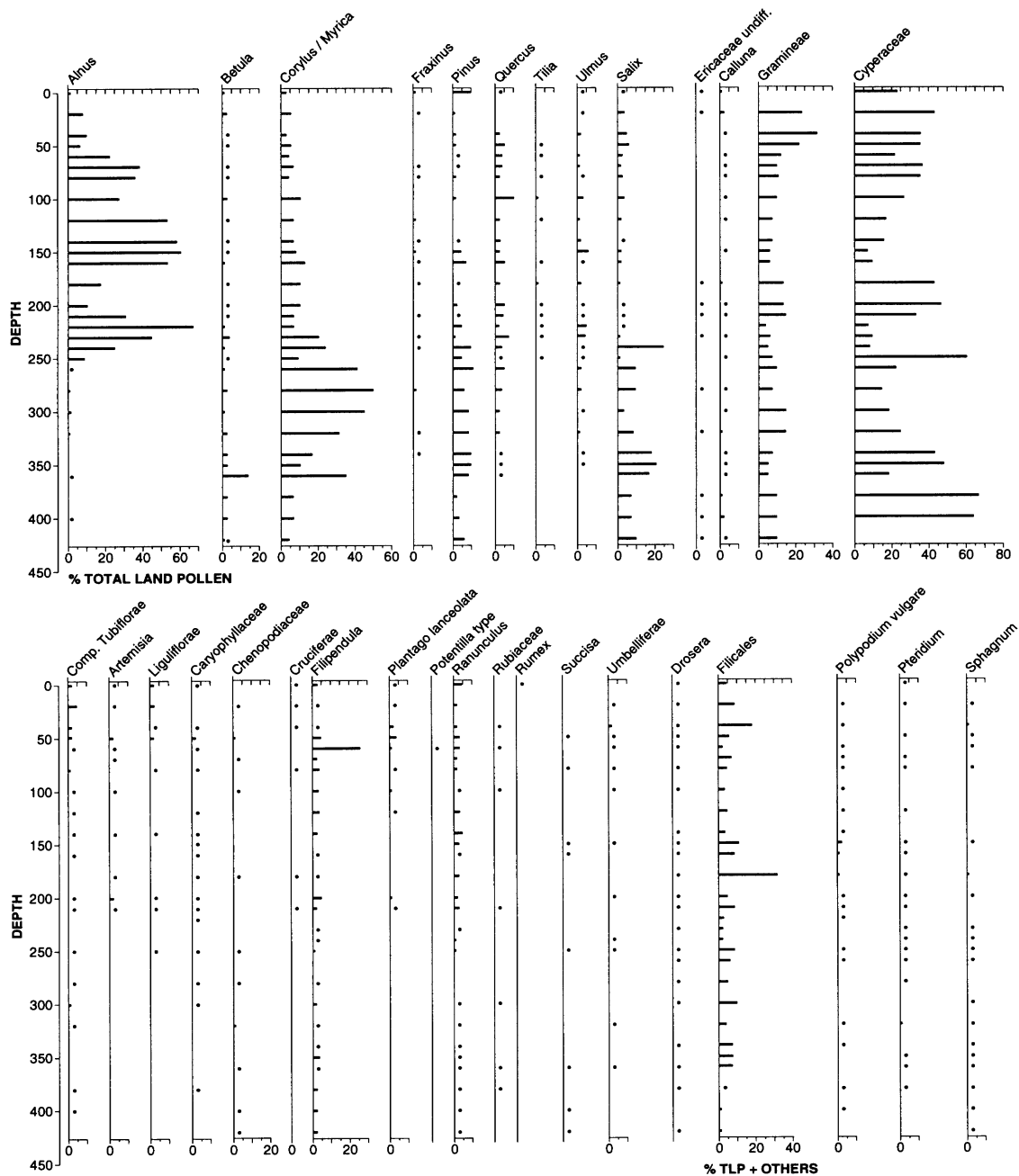


Figure 5. Total land pollen-based pollen diagram for the sediments at borehole M₂ (modified from data in Borek, 1975)

Interpretation

The peat at Akeld Steads is tucked against the edge of a fill of glaciodeltaic gravels (Figures 2 and 3; Clapperton, 1971), in part protected by these from lateral erosion by the River Glen. The slope of this gravel terrace at the northwest end of transect A–B between boreholes 12 and 11 (Figure 4) is oversteepened, the product of channel migration by the River Glen as far northwest as borehole 11, prior to the onset of peat

Table I. ^{14}C dates from the sediment stratigraphy at Akeld Steads (calibrations using CALIB 3.0)

Borehole	Depth (cm) + thickness	SRR–	^{14}C age BP ($\pm 1\sigma$)	$\delta^{13}\text{C}_{\text{PDB}}$ ($\pm 1\text{‰}$)	Cal. BP ($\pm 1\sigma$)
One (Date 1)	460.0–470.0	–5179	10080 \pm 45	–28.1	11 854–11 214
One (Date 2)	412.0–422.0	–5178	9940 \pm 40	–29.4	11 311–11 001
One (Date 3)	251.0–261.0	–5177	6510 \pm 45	–28.4	7393–7333
Ten (Date 4)	195.0–205.0	–5176	6575 \pm 45	–28.4	7512–7389
One (Date 5)	120.0–125.0	–5175	3710 \pm 45	–29.2	4123–3935
One (Date 6)	84.0–89.0	–5174	3320 \pm 45	–29.5	3622–3470
Ten (Date 7)	80.0–90.0	–5173	4070 \pm 40	–28.4	4786–4449
One (Date 8)	41.0–46.0	–5172	2730 \pm 45	–29.2	2858–2768

deposition. As a result of this bevelling of the glaciodeltaic deposits the peat–alluvial stratigraphy is formed on coarse sands and gravels; a base to boreholes 3 and 2 could not clearly be demonstrated during coring.

Isolated patches of peat began to form on the widened valley floor before 11 854–11 214 cal. BP (Date 1; Figure 4; *c.* 10 000 ^{14}C BP: SRR-5179), overlying finely banded fluvial sands. At borehole M_2 peat commenced formation before the *Corylus/Myrica* rise (Figure 5), dated to around 10 250 cal. BP (*c.* 9200 ^{14}C BP) at sites in southeast Scotland (Hibbert and Switsur, 1976; Boyd and Dickson, 1986; Birks, 1989; Innes and Shennan, 1991). An extrapolated date for peat formation at borehole M_2 would agree well with the ^{14}C assay SRR-5179 at around 11 500 cal. BP (10 250 ^{14}C BP).

This peat contains increasing amounts of clay, though with organic matter persisting, in a *c.* 40 cm thick minerogenic band (boreholes 1–4). The timespan covered by this unit cannot be separated on the ^{14}C dates SRR-5179 (Date 1) and SRR-5178 (Date 2) which bracket this event (Figure 4; Table I), suggesting rapid sedimentation, though this effect may be induced through radiocarbon ‘plateau’ effects (Ammann and Lotter, 1989) compressing the ^{14}C chronology.

Following this early Holocene phase a discrete spatial pattern of sedimentation is established across the floodplain. At the floodplain edge (boreholes 14–5) a herbaceous peat gives way to wood-rich peat (spp. unidentified) at around 10 000 cal. BP (9000 ^{14}C BP), which continued to form without incursions of minerogenic sediment until *c.* 7500 cal. BP (6550 ^{14}C BP). The valley floor peats were dominated by Cyperaceae, with *Salix* and a number of tall herbs, and *Alnus* after *c.* 8300 cal. BP (7400 ^{14}C BP) (Figure 5).

Towards the present River Glen the sediments are exclusively minerogenic, more varied than depicted in Figure 4, with clays and silts, occasionally with plant fragments, fine sands and broad bands of medium–coarse sand. These sediments are interpreted as overbank sediments deposited during flood phases. It is possible that the coarser units close to the river correlate with phases of finer-grained minerogenic deposition across the peat (below) but this is not demonstrable. There is no reason to assume that minerogenic aggradation represents continuous sedimentation, since Weatherston and Innes (unpublished data) record organic-rich buried ‘soils’ elsewhere in the Glen–Till zone of sedimentation. The chronology of sedimentation can only be established at the interface between organic and minerogenic facies.

Continuous peat accumulation came to an end at around 7500 cal. BP (6550 ^{14}C BP). Two ^{14}C assays (SRR-5177 (Date 3) and –5176 (Date 4)) were obtained from boreholes 45 m apart on what, on lithostratigraphic correlation (Figure 4), is the same peat–silty clay boundary. The intention was to measure the time taken for minerogenic sediments to spread across the peat surface, but the two assays are inseparable (SRR-5177: 7393–7333 cal. BP; SRR-5176: 7512–7389 cal. BP; Table I). It is possible that this comparability in age is through this being an erosive contact, but this is unlikely because the boundaries between organic and minerogenic facies are very gradual (from peat to clay-rich peat to peat-rich clay). It is considered that this earliest mid-Holocene minerogenic incursion is correctly dated, and was more-or-less instantaneous in its transgressive effect. It corresponds to a phase of markedly suppressed *Alnus* percentages and increased representation of wetland herbs such as Cyperaceae (Figure 5), and the incursion probably disturbed floodplain woods. There is a phase of virtually minerogenic silty fine sands in most boreholes affected (boreholes 1–10; Figure 4) that may characterize the peak period of flood deposits across the floodplain. Although rates of sedimentation are unlikely to be linear between assays SRR-5177 (Date 3) and –5175 (Date 5) in borehole 1 (Figure 4), this coarsest sediment was deposited sometime between 5400 and 4700 cal. BP (4700–4200 ^{14}C BP).

In borehole 10 the peat dated by ^{14}C assay 7 (Date 7; SRR-5173: 4768–4449 cal. BP) lies some 50 cm above this minerogenic band, yet yields a date older than peat in borehole 1 (Date 5: SRR-5175: 4123–3935 cal. BP) that more closely overlies the minerogenic band (Figure 4; Table I). It may be that towards the valley-side the phase of minerogenic sedimentation was replaced by peat significantly earlier than to riverward. Peat growth may have initially been rapid due to elevated water tables induced through frequent flooding across adjacent peats. If correctly interpreted, the replacement of peat over flood-phase sediments took some 500–700 cal. years between boreholes 10 and 1 (Figure 4; Table I) through a gradual reduction in flood events. As flood frequencies or energies waned and sediments became increasingly organic, *Alnus* woods may once more have colonized the floodplain (c. 160 cm in Figure 5).

At least one more phase of flooding sent minerogenic sediment spreading across the peat. After 3622–3470 cal. BP (c. 3320 ^{14}C BP: SRR-5174; Date 6; Figure 4; Table I) wood-rich peat was replaced between boreholes 7 and M₂ by increasingly minerogenic fluvially derived sediments (Figure 4). The end of this phase and re-establishment of peat has not been dated, but can be bracketed by the final replacement of peat by present-day mineral soil at 2858–2768 cal. BP (c. 2750 ^{14}C BP: SRR-5172; Table I). This soil is likely to have developed at least partly from sediment derived from flooding as it becomes increasingly minerogenic towards the present river, but in part it may have developed through *in situ* oxidation and mineralization of drained peat. The boundary between peat and soil may be a product of oxidation-associated processes so that the depth and resultant ^{14}C assay SRR-5172 (Date 8; Figure 4; Table I) need not be stratigraphically significant in itself. Sediment younger than 2800 cal. BP (2750 ^{14}C BP) has almost certainly been lost through oxidation.

THE AKELD STEADS SITE IN A REGIONAL CONTEXT

The stratigraphic record from Akeld Steads needs to be placed in context to understand its wider significance. In this the work of Clapperton (1970, 1971) and Payton (1980, 1988, 1992) in the Milfield Basin, and Clapperton *et al.* (1971) and Tipping (1992, 1994d, unpublished) in the major southerly tributary, the Wooler Water, and the Bowmont Valley (Figure 1), are most relevant.

Late Devensian evolution of the Milfield Basin

The earliest sediments overlying till in most of the Milfield Basin are laminated silts and clays and occasional interbedded sands (Figure 2), their maximum thickness unknown, regarded as proglacial glaciolacustrine sediments (Clapperton, 1971; Payton, 1980) deposited in a lake dammed to the north where drainage to the Tweed Basin was blocked, initially by stagnant Tweed ice, subsequently by a rock barrier at Etal (Figures 1 and 2). Glaciolacustrine sediments are found to an altitude of 45 m OD.

Laminated silt/clay couplet deposition ceased before the Lateglacial Interstadial. Payton (1988, 1992) recorded a buried humic gley soil developed in laminated silts and clays at Black Burn in the east of the basin (Figure 2), at 37 m OD. The buried topsoil (bApg) horizon of this soil gave a ^{14}C date of 11460 ± 100 BP (HAR-4308) (13 512–13 253 cal. BP). Since glaciolacustrine clays can be expected to occur at consistent altitudes through this single lake, this important dating control indicates that erosion of some 8 m of glaciolacustrine lake sediment occurred before the Lateglacial Interstadial, at least in this part of the basin.

Overlying the Black Burn palaeosol are further laminated lacustrine sediments, clays and silty clays high in Ca and Mg. Payton (1988) suggested these to be biogenic rather than density-graded laminates, deposited by seasonal physico-chemical controls. These younger lake sediments were formed after 13 512–13 253 cal. BP, either in the later stages of the Lateglacial Interstadial or in the Loch Lomond Stadial. They are found up to 40 m OD (Payton, 1988), implying a rise in lake level of at least 3 m from the time of formation of the Black Burn palaeosol. Payton argued that base-level changes induced by erosion of the Etal rock bar could not have been responsible for both lake-level lowering prior to the Lateglacial Interstadial and its subsequent rise, and that these must have occurred through changes in discharge and/or climate within a closed basin. This contrasts with Clapperton's (1971) view that lacustrine sedimentation was a phenomenon solely of deglaciation. The age of the youngest biogenic laminates is not known. However, they must be older than 11 854–11 214 cal. BP (SRR-5179), the base of the peat sequence at Akeld Steads (below).

Loch Lomond Stadial channel-trenching

The inferred rise in lake-level post-13 300 cal. BP is attributed by Payton (1988) to climatic deterioration in the latter part of the Lateglacial Interstadial or the Loch Lomond Stadial. However, between c. 13 300 cal. BP, the date of the Black Burn palaeosol, and c. 11 500 cal. BP, the base of the Akeld Steads peat sequence, there must also have occurred downcutting and a lowering of the local base-level at Akeld Steads of some 6 m, from c. 40 m OD to c. 33.5 m OD at the base of boreholes 1–4 at Akeld Steads (Figure 4).

To the south of the Milfield Basin the Wooler Water near Earle Mill (Figures 1 and 2) can be suggested to show a similar pattern of vertical channel incision at around this time, though the dating is less secure. The Wooler Water at this point is bordered to the west on the lower slopes of the Cheviots by fluvio-glacial gravels. To the east a broad (500 m wide) fluvial gravel terrace, the Haugh Head Terrace (Clapperton *et al.*'s (1971) 'gravel plain') was incised some 18 m below the surface of the fluvio-glacial deposits before c. 3 m of coarse bouldery gravels were aggraded (Tipping, 1994d). The Haugh Head Terrace is dated to some time in the Late Devensian. It is post-deglaciation, and section descriptions reported by Clapperton (1967) near Earle Mill describe the Haugh Head gravels overlying glaciolacustrine laminated sediments. The Haugh Head Terrace surface was abandoned by down-cutting of some 8 m during the earliest Holocene or in the latter part of the Loch Lomond Stadial. Pollen analyses by Squires (Clapperton *et al.*, 1971) suggest that the newly cut valley floor supported a *Phragmites*–*Carex* peat before the early Holocene colonization of *Betula*, dated to around 11 500–10 570 cal. BP (Birks, 1989). Incision may have occurred within the Loch Lomond Stadial, a similar pattern to that suggested at Akeld Steads.

Considerable amounts of down-cutting occurred at both sites before the earliest Holocene, most likely within the Loch Lomond Stadial. This phase of incision may represent a local response to lowered base-levels controlled by down-cutting within the Etal gorge, but at Akeld Steads and probably in the Wooler Water, valley floor widening and floodplain-edge erosion also occurred, which represents a considerable degree of accelerated geomorphic activity. It is likely, therefore, that down-cutting of the Etal rock bar was not directly causal in down-cutting in the basin, but that the same increase in fluvial activity that generated channel incision in the basin eroded the rock bar downstream.

Similar changes in river behaviour within the Younger Dryas/Loch Lomond Stadial are known elsewhere in Europe (Rose and Boardman, 1983; Brown, 1995; Starkel, 1995), though in most instances the observed changes are in planform, from single-thread to braided channels, rather than in rates of vertical incision. Gaunt *et al.* (1971) have reported stream incision of the Vale of York at the end of the Devensian Lateglacial, and Rose (1995) has more comprehensively identified stream incision at the end of the Younger Dryas/Loch Lomond Stadial in lowland Britain. Maizels and Aitken (1991) also suggested that incision may have occurred at the beginning of the Younger Dryas/Loch Lomond Stadial in northeast Scottish upland valleys, but they have no reliable chronological controls.

Accelerated fluvial activity in the stadial is considered by Rose (1995) and Vandenberghe (1995) to be a product of increased discharge through high snow-melt and high sediment yield through gelifluction and very low vegetation cover. Payton (1992) has suggested that fossil ice-wedges in the Milfield Basin are of Loch Lomond Stadial age, and Harrison (1994) suggests that at least one north-facing corrie in the Cheviot Hills, at the Bizzle within the drainage system of the River Glen, contained glacier ice in the stadial. Rose's (1995) model suggests that incision would have occurred at a point where steep upland streams meet low-relief valley stretches, as at Akeld Steads. The downstream expression of this incision in the Milfield Basin has not been explored.

Holocene alluviation

Following channel-trenching there is stratigraphic evidence at Akeld Steads for continued fluvial activity in the earliest Holocene, albeit the deposition only of organic-rich clays across the widened valley floor. This phase ceased quickly, however, and the early Holocene record indicates an absence of measurable fluvial deposition until c. 7500 cal. BP. This finding is in accord with syntheses (e.g. Macklin and Lewin, 1994) that suggest prolonged periods of landscape stability in the first part of the present interglacial.

At around 7500 cal. BP this stable landscape is disturbed by a phase of overbank deposition. This may not have been sustained until 4000–3500 cal. BP, but had ceased by this later date. A phase of coarse sediment deposition is noted between 5400 and 4700 cal. BP (above). In the upland Cheviot valleys analysed by Tipping (1992) the earliest recorded phase of accelerated fluvial activity is after 4400–4000 cal. BP. The apparent diachroneity between these data is strengthened when two sediment records from within the upper reaches of the Glen–Bowmont catchment itself are examined. At Yetholm Loch (Figure 1) organic-rich lake muds are replaced gradually by increasingly minerogenic clays and silts from c. 5000 cal. BP onwards, whilst within the Halter Burn, a tributary of the Bowmont Water (Figure 1), the earliest recorded Holocene gravel aggradation is after c. 4400 cal. BP (Tipping, 1992). These upstream events are probably recorded within the Akelds Steads sequence, but the onset of alluviation at Akeld Steads has no correlative upstream. At Halter Burn the first recorded event may not be the earliest, but the Yetholm Loch sequence is a continuous and full Holocene sediment-stratigraphic record (Tipping, unpublished data).

It is possible that the Akeld Steads ^{14}C dates for the onset of overbank sediment are on erosional contacts but this is felt unlikely (above). It is more likely that the Akelds Steads site appears to demonstrate landscape disturbance in a lowland setting at a time significantly earlier than towards the headwaters. Such spatial variability and temporal diachroneity in fluvial change may be more apparent than real. Schumm's (1977) identification of complex responses to a single stimulus in a fluvial system, where the system expresses change in different ways in different parts of the system, might explain the pattern. For instance, there may be no record at Halter Burn through change being either solely erosional (e.g. channel-trenching) or through within-channel adjustments, invisible in the palaeohydrological record. Conversely, the spatial and temporal patterning may be real, and if so is likely to reflect a cause that operates at a local scale. For this reason the event is unlikely to imply climatic causation (cf. Starkel, 1991). However, in the absence at present of a method to establish the nature of the fluvial events identified, it is fruitless to speculate further: hence the emphasis here on chronology not cause (cf. Tipping and Halliday, 1994).

The cessation of this phase of alluviation at Akeld Steads between 4000 and 3500 cal. BP is close to the time of the major sediment-forming fluvial events in upland Cheviot valleys such as the Halter Burn (above) and the Wooler Water. One weakness in the chronology of cut-and-fill terrace sequences is the frequent difficulty in defining the duration of terrace aggradations. In the Cheviot uplands it is the onset of this phase that is dated (Tipping, 1992), and it is not possible to define its end. In the stacked fill at Akeld Steads the end of this phase can be successfully defined as between 4000 and 3500 cal. BP. Sediment availability is not a limiting factor in sustaining alluvial processes, since there are continuous spreads of fluvio-glacial terracing still accessible to stream bank erosion. Stratigraphic work (Payton, 1980; Weatherston and Innes, unpublished data) indicates that channels in the Milfield Basin have probably been stable for most of the Holocene, so that unless the capacity of the channel to contain flood events increased, which is possible, externally driven causes for a reduction in overbank sedimentation appear likely.

Tipping (1992) argued for Bronze Age human activity in the uplands (Burgess, 1984) to have induced soil erosion at 4400–4000 cal. BP, although climatic deterioration (Mannion, 1982; Barber *et al.*, 1994) may have been important also (Tipping, 1994b). The cessation of this accelerated fluvial activity as measured at Akeld Steads has implications for these competing though not mutually exclusive causal agents. For example, the period c. 3500 cal. BP lies within the trend to increasing precipitation. Slope and fluvial stabilization under a period of continued, albeit perhaps less intense, climatic downturn might seem unlikely. Equally, whilst the scale of Bronze Age upland settlement in the Cheviots remains hotly debated (Burgess, 1995), there is little evidence of a reduction in activity from the archaeological record (Burgess, 1990), poorly dated though it is. However, at both Yetholm Loch and further within the Bowmont headwaters at Swindon Hill (Figure 1) there is some palynological evidence for woodland regeneration at around 3300 ^{14}C BP (3500 cal. BP; Tipping, 1992). The regional significance of these vegetation changes is still unclear, but the palaeohydrological data evaluated here might suggest that forest regeneration in a period of reduced anthropogenic interest in the hills had a significant effect on downstream fluvial sedimentation.

CONCLUSIONS

A simple stratified sequence of Holocene valley-floor peats and interdigitating fluvial flood sediments has allowed the first ^{14}C dated reconstruction of Late Quaternary geomorphic events in northern England's largest alluvial basin.

The scale of Late Devensian glacio-deltaic and glacio-lacustrine deposition has long been established (Butler, 1907; Clapperton, 1970). This reconstruction places considerable emphasis on two phases of pronounced channel-trenching. The earlier, recorded at Wooler, is undated, but the later and more significant event seen at several sites is constrained in time to the Loch Lomond Stadial.

The early Holocene, prior to 7500 cal. BP, is a time of channel stability and relative quiescence, again seen throughout Britain (Macklin and Lewin, 1994) and Europe (Starkel, 1995). The onset of mid-Holocene accelerated fluvial activity after 7500 cal. BP is problematic in interpretation and ambiguous in origin, but the cessation of overbank sedimentation after c. 3500 cal. BP may be controlled by increasing slope stability under reforested conditions in the Cheviot headwaters.

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